# FIREWORKS REMOTE CONTROL SYSTEM

## FIELD OF THE INVENTION

The present invention relates to control systems generally, and in particular, to a control system for activating a distributed set of fireworks actuators in a sequential fashion.

## BACKGROUND OF THE INVENTION

Existing fireworks control systems generally require an extensive cable network connecting between the distribution box and the squib or electropyrotechnical match-head that initiates the fireworks. The work associated with laying such a cable network is an expensive and time-consuming operation and imposes severe limitations as result of local topographic elements, such as roads, fences, buildings, electric cables, lakes, rivers, pools, trees and vegetation. The cables are frequently damaged as a result of the movement of people or vehicles in the deployment area. The cables are generally for one-time use and significant time is required for removal and disposing.

The prior art includes solutions to the problem of physical cable networks for a plurality of distributed, remotely activated squibs, by use of wireless command and activation systems. For example, in US Patent No. 4,884,506 to Guerreri, there is disclosed a remote detonation system for explosive charges, which uses a wireless duplex, encoded system.

Fireworks control systems require in some cases, hundreds of individual, distributed control units. Existing wireless control systems which require a high level of reliability, safety and accuracy, are generally based on duplex communications, which enables the central control unit to confirm the signals received by the remote units. However, this increases the cost of these systems, and increases the power consumption levels, and generally presents problems with respect to compliance with FCC Part 15 requirements. This is because the FCC Part 15 requirements place strict limitations on

the duration of permitted wireless transmissions, and thus, the remote control systems cannot handle the large number of duplex transmissions with the required accuracy within the allotted time periods. Inability to meet these requirements results in a design which is less attractive to the user.

Therefore, it would be desirable to have a simplified system of controlling fireworks displays, which does not require significant time for installation, does not suffer from the drawbacks of the prior art cable network system control approach, and benefits from the wireless system approach, regarding cost, power consumption and reliability.

## SUMMARY OF THE INVENTION

The system of the present invention has been designed to overcome the above-mentioned limitations, by providing a remote control system in which each firework is connected to an individual firing unit, with a plurality of units being activated by wireless command from a terminal unit. This feature ensures complete flexibility in the location of each individual firework.

Accordingly, the present invention provides a remote control firing system for fireworks and pyrotechnics, comprising a central control unit to be referred hereinafter as the terminal unit (TU) and multiple individual remote firing units, with a radio frequency (RF) link for communication between the central and remote firing units. The wireless link is based on a simplex approach, using one-way communication, which achieves a simple, low cost system, without sacrificing a high level of reliability and performance.

The inventive system comprises a wireless activation system for pyrotechnic applications, such as fireworks. The system comprises a terminal unit (TU) and a plurality of remote activation units (RAU), and activates the multiple remote activation units in a desired sequence. The terminal unit and the remote activation units are each equipped with an independent power supply and are controlled by a microprocessor. Each TU is equipped with a transmitter and each RAU is equipped with a receiver. Each RAU can activate one or more electric squibs.

Each TU is equipped with a unique ID code. The RAUs are manufactured as generic units, each of which is capable of being assigned to a unique terminal unit, by programming it with the terminal unit ID code, by the user. The TU controls the RAU units by RF communication, and the RAUs can be activated from the TU by manually determined sequence or by a preprogrammed sequence inputted into the TU.

In the manual mode, the activation command is delivered individually to each RAU from the TU. In the preprogrammed (automatic) mode, a multitude of RAUs are activated in a predefined sequence.

The system includes power saving features for periods when not in use, and also features a safety mechanism comprising a beacon signal, that when discontinued (in case of communication failure), will cause disabling of the remote activation units.

Other features and advantages of the invention will become apparent from the following drawings and description.

## BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the invention with regard to the embodiments thereof, reference is made to the accompanying drawings, in which like numerals designate corresponding elements or sections throughout, and in which:

Fig. 1 is a system layout of the inventive fireworks remote control system, constructed and operated in accordance with the principles of the present invention;

Fig. 2 is a block diagram of a terminal unit of the inventive system;

Fig. 3 is a block diagram of a remote activation unit of the inventive system;

Fig. 4 is a flowchart of the operation of the terminal unit of the inventive system; and

Fig. 5 is a flowchart of the operation of the remote activation units of the inventive system.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Referring now to Fig. 1, there is shown a system layout of the inventive fireworks remote control system 10, comprising a terminal unit 12 and a plurality of 1....k remote activation units 14. The central terminal unit (TU) 12 and remote activation units (RAU) 14 are linked by RF communication link.

The RF communication link is encoded in a way that provides each RAU 14 with two ID numbers, one is a unique ID number of terminal unit 12 and the second one is a serial ID number of the RAU 14. The terminal unit 12 unique ID is set during production. The number is long enough so that it will never repeat itself. In the RAU 14, the terminal unit ID and the serial ID are not programmed in production and the RAU unit 14 is initially set in a generic state.

When the user puts together a complete system comprised of one terminal unit 12 and multiple remote individual firing remote activation units 14, the user attributes the control unit ID and serial ID to each RAU 14, using the RF link or a cable. This procedure can be repeated an unlimited number of times. Several RAU units 14 can be assigned the same ID and in that case they will operate simultaneously. Any remote activation unit can be reprogrammed to different ID's if so desired.

The system 10 has two modes of operation, manual and automatic. In the manual mode, the terminal unit 12 can activate each firing unit on demand by sending it the firing command designated for a unique remote activation unit 14 (or for several units having the same ID). In the automatic mode, each unique remote activation unit 14 is programmed to operate at a specific time inserted into the terminal unit 12 in advance.

The remote activation unit 14 operates in a sequential manner which prevents unintentional firing. The user first delivers to the remote units an enable command from the terminal unit 12. Later the user delivers from the terminal unit 12 to the remote units 14 the firing or ignition command either individually (in the manual mode) or as a group (in the automatic mode). The user can deliver from the terminal unit 12 a disable command which will disable the remote activation units 14 as a group.

As previously explained, in automatic mode each individual remote activation unit 14 operates at a different preset time. To increase the safety of the system operation, the firing sequence may need to be interrupted, and a system mechanism for providing the interruption is needed in this case. It may be understood that the transmission of a stop command sent from the terminal unit 12 to the individual remote activation units 14 may not be sufficient, since the broadcast of a stop command may not reach the remote activation unit 14 in the case of a failure of the RF link. To overcome this safety hazard, the system operates in a fail-safe mode, by use of a beacon signal, which is periodically broadcast by the terminal unit 12 to the remote activation units 14. If an RAU 14 ceases to receive the beacon signal, it will not activate the fireworks.

It is a particular feature of the present invention that the beacon signal enables complete control of the RAU's 14 with a high level of reliability, even though the system relies on a simplex approach, using one-way communication. The reception of the beacon signal at the RAU 14 is the mandatory condition under which the RAU 14 can be activated, and therefore, if the firing sequence is to be interrupted, it is not necessary to verify the receipt of a stop command at each RAU 14, as in the prior art duplex communication systems. This feature enables the simplex approach to achieve a high level of reliability, while maintaining a low cost and simplicity of design.

It will be appreciated by those skilled in the art that in certain cases, the existing remote activation systems are incapable of achieving this level of reliability and safety. If, for example, there is a total blockage of wireless communications by partial system failure, or environmental conditions which interfere or prevent such communications, existing systems have no way to interrupt a firing sequence already in progress, since they cannot communicate with the remote units. In contrast, in the inventive system, such a failure would interrupt the firing sequence already in progress, since the beacon signal would not be received by the RAU 14, and no firing would occur.

In order to save battery life, when the user turns off the terminal unit 12, a sleep command is sent from this unit to all the individual remote activation units 14. The units themselves will then be maintained in a state of very low power consumption. When the

user again turns on the terminal unit 12, it will send a wakeup command to each individual remote activation unit 14.

Referring now to Fig. 2, there is shown a block diagram of a terminal unit 12 of the inventive system 10. Central unit 12 comprises an antenna 16, which enables broadcast of the RF signals from a transmitter 18, which is controlled by its connection to a microprocessor-based logical unit 20. Unit 20 is connected to a keypad 22 for programming and control. A display 26 is provided for the user for assistance in programming unit 20, or reviewing system status information. A central safety key 28 is provided for enabling or disabling the operation of the logical unit 20, and this allows for supervisory control of system operation by the user. A local power supply 30 and a connection to an external power supply 32 are also provided.

Referring now to Fig. 3, there is shown a block diagram of a remote activation unit 14 of the inventive system. Remote activation unit 14 comprises an antenna 34, which enables reception via receiver 36 of the RF signals from terminal unit 12. Receiver 36 provides the information contained in the demodulated RF signals to a microprocessor –based logical unit 38. Unit 38 is connected to and controls a firing circuit 40, which enables the firing of the fireworks of the remote activation unit 14, via the connection element 42 which contacts the match-head. The remote unit is equipped with a power supply (battery) 39.

It will be appreciated that the specific design of the central 12 and remote activation units 14 will be in accordance with skill of the art electronic design techniques, to provide a reliable, efficient and easy-to-use system which is reasonable in cost.

Referring now to Fig. 4, there is shown a flowchart of the operation of the terminal unit of the inventive system, under control of logical unit 20. The inventive system is based on a terminal unit 12 having an ID number which is linked in more than one possible way including RF to a series of remote units 14 to control the operation of the remote units 14 which ignite the fireworks. Prior to the beginning stage of operation of the fireworks system 10, the individual remote units are taken and programmed individually for the operation which will be controlled at a later stage

by the terminal unit 12, and communication tests between the terminal and remote units are conducted.

The operation of the flow chart begins in block 50 with the terminal unit 12 being turned on. At this point, a selection is made in block 58 whether to operate the system in an automatic or manual mode. If at the decision block 60 the operator's choice is to go to the manual mode 61, then in command block 62, a command is sent at a time the operator chooses, enabling all of the remote units 14, so that they charge their capacitors in preparation of firing. After the enable command is sent, a decision block 64 is reached in which the opportunity to disable the command is given and if that is done, the system reverts to the input of block 62. If in fact the disable command was not given in block 64 so that the enable command is still effective, then individual firing commands can be sent to the individual remote units 14 .

The individual firing commands are sent in block 69 by depressing a button on a control panel which is labeled with the code of the individual remote units 14. By depressing this button the individual remote unit 14 is sent an activation command to ignite the fireworks connected to it. Each individual remote unit 14 contains one fireworks but there may be multiple units having the same code so that depressing that one button on the control panel will set off several remote units 14 all corresponding to that same button, to that single code. After each individual firing command the system reverts to the input of block 64.

The automatic mode block 72 is entered by the appropriate response to the decision block 60 where the selection is determined. The automatic mode relates to a sequence of firing the individual remote units 14 based on a pre-programmed sequence. If at decision block 60 the operator's choice is to go to the automatic mode 72, then a command is sent in command block 74 at a time the operator chooses, enabling all of the remote units 14, so that they charge their capacitors in preparation of firing. After the enable command is sent, decision block 76 is reached, in which the opportunity to disable the command is given and if that is done, the system reverts to the input of block 74.

If the enable command is not disabled in block 76, the operation continues to the point at which the operator initiates the automatic fire sequence in block 82. The

automatic fire sequence is sent to each of the individual remote units 14. It consists of a delay time ($\Delta T$) for the operation of that unit 14 relative to the start of the automatic fire sequence. From the start of the automatic fire sequence the delay times are sent so that each individual remote unit 14 knows how much delay time must elapse before initiating its firing, and in the meanwhile, upon initiation of the automatic fire sequence in block 82, a beacon signal is initiated by the operator in block 84 from the terminal unit 12. This beacon signal is a repetitive signal which is received by each individual remote unit 14 and in the presence of the existing beacon signal which has been received on this repetitive basis, the individual remote unit 14 will become activated when its delay time ($\Delta T$) for firing has elapsed.

If however, the beacon signal is not present at the time the individual remote unit 14 is supposed to be activated, it will not be activated and it will be skipped. This means that if the user decides not to provide the beacon signal at block 88 for a certain period, so that it is discontinued, all of the units that were supposed to be activated during that period will not be activated and the operation will loop to block 84. If the beacon signal is then restored after that time period, all of the additional units that will be going into operation later will continue to operate normally, and the operation will end in block 94. So, by use of the beacon signal, the option exists to skip over certain individual remote units 14.

Referring now to Fig. 5, the remote unit 14 is described by the flow chart, and the operation begins by having unit 14 turned on in block 102, and then remote unit 14 is checked in block 104 to see whether or not it is enabled. It is looking for the enable command, and if it does not receive it, then it will operate in loop fashion until the enable command is received. If the enable command has been received in block 104, then the operation checks in block 105 whether the mode of operation is manual or automatic. If the mode of operation is manual, the remote unit is set at block 107 to manual mode and the capacitor is charged to make the firing circuit ready at block 108. The remote unit 14 checks at block 109 whether or not a disable command has been received. If so, the loop begins from the beginning to see whether or not it is enabled once again.

If the remote unit 14 has not been disabled, then it is waiting in block 110 for a firing signal to be received, and if the firing signal is not received, then the operation will loop within the previous loop to ask whether or not the remote unit 14 is disabled. If in the meanwhile, the firing signal has been received in block 110, the fireworks are activated immediately in block 111.

If the mode of operation is automatic, the remote unit is set at block 112 to automatic mode, the time delay ($\Delta T$) is set at block 113 and the capacitor is charged to make the firing circuit ready at block 114. The remote unit 14 checks at block 115 whether or not a disable command has been received. If so, the loop begins from the beginning to see whether or not it is enabled once again.

If the remote unit 14 has not been disabled, then it is waiting in block 116 for a signal for the start of the automatic sequence, and if the start signal is not received, then the operation will loop within the previous loop to ask whether or not the remote unit 14 is disabled. If in the meanwhile, the start signal has been received in block 116, the remote unit 14 checks in block 117 whether the beacon signal has been received. If no, the unit checks at block 118 whether the delay time has elapsed. Until the delay time has elapsed, the unit will be looping and awaiting the beacon signal. After the delay time has elapsed, the remote unit will disarm at block 119. If the beacon signal has received, the unit checks at block 120 whether the delay time has elapsed. Until the delay time has elapsed, the unit will be looping and awaiting the continuing beacon signal. After the delay time has elapsed, the remote unit will activate the fireworks at block 111.

In summary, the present invention provides a remote control firing system for fireworks and pyrotechnics which achieves a simple, low cost system, without sacrificing a high level of reliability and performance.

Having described the invention with regard to certain specific embodiments, it is to be understood that the description is not meant as a limitation, since further modifications may now suggest themselves to those skilled in the art, and it is intended to cover such modifications as fall within the scope of the appended claims.